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REGULAR ARTICLE

Association between lifestyle-related disorders and visceral fat mass in Japanese males: a hospital based cross-sectional study

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Abstract
Objective This study aimed to examine the association between lifestyle-related disorders and visceral fat mass, and to estimate an appropriate cutoff value for visceral fat mass that correlated with body mass index (BMI) and waist circumference (WC).
Methods This cross-sectional study was conducted between July 2012 and August 2013 at Bange Kosei General Hospital, in Fukushima, Japan. All study participants were adult males who had completed voluntary medical check-ups that included estimation of visceral fat mass by bioelectrical impedance analysis (BIA). Participants were without past histories of atherosclerotic complications or were not currently taking medications for lifestyle-related disorders. Multivariate analysis was performed to estimate the association between lifestyle-related disorders and quartiles of visceral fat mass.
Results Of 536 total respondents, 442 were included in the analysis. Mean participant age was 56 years, and mean values of BMI, WC, and visceral fat mass were 24.1 kg/m^2, 85.9 cm, and 2.1 kg, respectively. Visceral fat mass $\geq$1.8 kg was positively associated with an increased prevalence of dyslipidemia, elevated blood pressure, and impaired glucose tolerance. Cutoff values that correlated with visceral fat mass ($\geq$1.8 kg) were 85.3 cm for WC and 23.25 kg/m^2 for BMI.
Conclusion Visceral fat mass $\geq$1.8 kg was positively associated with lifestyle-related disorders and closely related to WC and BMI cutoff values used to diagnose obesity. BIA may be a useful method for assessing visceral

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fat mass, and these findings provide important evidence for the use of BIA in the early detection of central obesity for preventing lifestyle-related disorders.

Keywords Obesity · Lifestyle-related disorders · Bioelectrical impedance analysis · Prevention · Visceral fat

Introduction

Obesity is an important risk factor for the development of diabetes mellitus, hypertension, and dyslipidemia, and a strong predictor of increased morbidity and mortality [1, 2]. Body mass index (BMI) has traditionally been used to assess obesity. However, both the importance of the body distribution of excess weight, and the relationship between regional fat deposits and disease onset, has recently been recognized [3]. Visceral adipose tissue, which is deposited in the intra-abdominal cavity and surrounds internal organs, has attracted considerable attention based on its association with metabolic risk factors as well as morbidity and mortality [4, 5].

Currently accepted methods for measuring visceral fat mass are computed tomography (CT) and magnetic resonance imaging (MRI) [6, 7]. However, there are several concerns with these techniques, which are expensive and time-consuming. In addition, CT imaging involves exposure to radiation. Therefore, its use in measuring visceral fat mass as a part of routine health check-ups is not feasible. Waist circumference (WC) is widely used in medical and health check-ups as an anthropometric measurement to assess visceral fat accumulation [7]. However, WC does not differentiate between subcutaneous and visceral fat, and is affected by age, sex, BMI, ethnicity, and other factors [8].

Bioelectrical impedance analysis (BIA), a recently established method of analyzing visceral fat mass and whole body mass, is strongly correlated with visceral fat mass estimated by CT or MRI [9, 10]. Although BIA is convenient and non-invasive, epidemiological assessment is limited and few studies have examined the association between BIA-measured visceral fat mass and lifestyle-related disorders. This study aimed to examine the correlation between visceral fat mass and WC or BMI, clarify the association between visceral fat mass and lifestyle-related disorders, and to estimate an appropriate cutoff value for visceral fat mass that correlates with an increased risk of developing lifestyle-related disorders.

Materials and methods

This cross-sectional study was conducted between July 2012 and August 2013 at Bange Kosei General Hospital in Fukushima Prefecture, Japan. Data were collected from 536 adult men who completed voluntary medical check-ups, and had their amounts of visceral fat measured using a BIA automated body composition analyzer. Ninety-four men were excluded from analysis due to use of medications for hypertension, dyslipidemia, or diabetes mellitus, and/or past history of cardiovascular disease or cerebrovascular disease. Thus, the final analysis was based on data collected from 442 adult men.

Automated body composition analysis using BIA

Participants were instructed not to participate in strenuous exercise for at least 4 hours before body composition measurements. Visceral fat mass was estimated using a multifrequency BIA device with tetra-polar electrodes (X Scan Plus, Jawon Medical Co., Ltd., Seoul City, Korea). BIA was performed by placing electrodes on the hands and ankles of participants, who were instructed to stand upright and hold both hands at 45° angles from the body. The device used frequencies of 1, 5, 50, 250, 550, and 1,000 kHz to analyze intra- and extracellular fluid volume and water composition. Thereafter, the device automatically calculated visceral fat mass (kg). A previous study showed that visceral fat area measured by CT scan was significantly correlated with that estimated by the BIA method ($r = 0.870$, $P < 0.001$) [11].

Variables

Body height, weight, and WC were measured in the standing position. BMI was calculated by dividing body weight (kg) by height squared (m^2). Both systolic blood pressure (SBP) and diastolic blood pressure (DBP) were calculated based on the mean of two upper arm blood pressure measurements on participants who had been seated for at least 5 mins. Serum levels of total cholesterol (mg/dL; TC), high-density lipoprotein cholesterol (mg/dL; HDL-C), low-density lipoprotein cholesterol (mg/dL; LDL-C), and triglycerides (mg/dL; TG) were also measured. LDL-C was estimated using the Friedewald equation [(TC)—(HDL-C)—(TG/5)]. Glycosylated hemoglobin A1c (HbA1c) levels were determined by high-performance liquid chromatography using an automated analyzer. HbA1c [Japanese Diabetes Society (JDS; %)] values were converted to a National Glycohemoglobin Standardization Program (NGSP) equivalent value using the following formula: HbA1c (NGSP) (%) = 1.02 × HbA1c (JDS) (%) + 0.25 % [12].

Participants were asked to complete a self-administrated questionnaire, which addressed healthy lifestyle characteristics according to Breslow's seven health practices [13]. These characteristics are useful in assessing healthy

lifestyle characteristics, and strong associations have been shown between healthy lifestyle items and blood pressure control among patients with hypertension [14]. Healthy lifestyle items in the questionnaire included alcohol consumption (non-daily drinker), smoking behavior (non-smoker), exercise frequency (two or more times per week), body mass index (18.5–24.9 kg/m^2), hours of sleep (six–nine), breakfast practices (every morning), and snacking between meals (none) according to Breslow's seven health practices [13–15].

Statistical analysis

Results are presented as mean ± standard deviation (SD) for continuous variables or prevalence (%) for categorical variables. Lifestyle-related disorders were assessed with the following criteria: elevated blood pressure (SBP $\geq$ 140 mmHg and/or DBP $\geq$ 90 mmHg), dyslipidemia (LDL-C $\geq$ 140 mg/dL, and/or HDL-C $<$ 40 mg/dL, and/or TG $\geq$ 150 mg/dL), and impaired glucose tolerance (HbA1c $\geq$ 6.0 %). Dyslipidemia was diagnosed according to the diagnostic criteria for dyslipidemia of the Japan Atherosclerosis Society [16]. The third criterion was based on the Japan Diabetes Society (JDS) recommendation that subjects with levels of HbA1c $\geq$ 6.0 % undergo a 75 % oral glucose tolerance test (OGTT). Values for visceral fat mass were categorized into quartiles (Q1 $\leq$ 1.2, 1.2 $<$ Q2 $\leq$ 1.8, 1.8 $<$ Q3 $\leq$ 2.5, 2.5 $<$ Q4). Trends in *P* values were estimated using the Jonckheere–Terpstra test for continuous variables and the Cochran–Armitage two-sided test for categorical variables.

To estimate the correlation between visceral fat mass and lifestyle-related disorders, logistic regression analysis was performed using bivariate analysis and two multivariate models. Bivariate analysis was adjusted for age (10 year increase), Model 1 was adjusted for age (10 year increase) and BMI (18.5–24.9), and Model 2 was adjusted for age (10 year increase) and total number of healthy lifestyle items.

Correlations between visceral fat mass and WC or BMI were estimated using the Pearson product-moment correlation coefficient. Receiver operating characteristic (ROC) curve analysis was used to assess appropriate cutoff values, estimate areas under the curves (AUC), and measure the sensitivity and specificity of visceral fat mass ($\geq$1.8 kg) associations with WC and BMI, also elevated blood pressure, dyslipidemia, and impaired glucose tolerance.

All significance tests were two-sided, and *P* values less than 0.05 were considered statistically significant. All data were analyzed using SPSS version 22 (IBM SPSS Inc., Chicago, USA).

This survey was conducted in compliance with the Ethical Guidelines for Epidemiological Studies established by the Japanese Government [17], and in accordance with the Declaration of Helsinki of 1975 (revised in 2000) [18]. The research protocol was reviewed and approved by the Fukushima Welfare Federation of Agricultural Cooperatives Council. Informed consent was obtained from all the participants of the study in written form.

Results

Table 1 shows the baseline clinical characteristics of the 422 participants [mean age, 56 (SD, 8.8) years]. Means of BMI, WC, and visceral fat mass were 24.1 (3.1) kg/m^2, 85.9 (8.1) cm, and 2.1 (1.0) kg, respectively. Means of SBP and DBP were 133.3 (18.2) and 80.1(12.0) mmHg, respectively. Lipid measurements were as follows: HDL-C 57.9 (15.1) mg/dL, LDL-C 125.3 (28.2) mg/dL, and TG 159.1 (122.6) mg/dL. Mean HbA1c was 5.67 (0.88) %, and the average total number of healthy lifestyle items was 4.9 (1.3).

Table 1 Baseline participant characteristics ($N = 422$)

	Number (%) or mean (standard deviation)
Age (years)	56.0 (8.8)
Anthropometric measurements	
Body mass index (BMI) (kg/m^2)	24.1 (3.1)
Waist circumference (WC) (cm)	85.9 (8.1)
Visceral fat mass (kg)	2.1 (1.0)
Blood pressure-related factors	
Systolic blood pressure (mmHg)	133.3 (18.2)
Diastolic blood pressure (mmHg)	80.1 (12.0)
Lipid-related items	
High-density lipoprotein cholesterol (HDL-C) (mg/dL)	57.9 (15.1)
Low-density lipoprotein cholesterol (LDL-C) (mg/dL)	125.3 (28.2)
Triglycerides (TG) (mg/dL)	159.1 (122.6)
Glucose-related items	
Hemoglobin A1c (HbA1c) (%)	5.67 (0.88)
Healthy lifestyle characteristics	
Alcohol consumption (non-drinker or moderate consumption)	372 (84.2)
Smoking behavior (non-current smoker)	287 (64.9)
Exercise frequency (two or more times per week)	133 (30.1)
Body mass index (18.5–24.9)	274 (62.0)
Hours of sleep (6–9)	324 (73.3)
Breakfast (every morning)	399 (90.3)
Snacking between meals (none)	385 (87.1)
Total number of healthy lifestyle items	4.9 (1.3)

Table 2 Visceral fat mass: specific characteristics

Visceral fat mass (kg)	Number (%) or Mean (Standard deviation)				
	Q1 ≤ 1.2 ($N = 84$)	1.2 < Q2 ≤ 1.8 ($N = 120$)	1.8 < Q3 ≤ 2.5 ($N = 125$)	2.5 < Q4 ($N = 113$)	P^a
Age (years)	56.0 (9.8)	56.5 (7.8)	56.3 (8.6)	55.3 (9.1)	0.51
Anthropometric measurements					
Body mass index (BMI) (kg/m^2)	20.7 (1.5)	22.5 (1.8)	24.7 (1.5)	27.6 (2.3)	<0.01
Waist circumference (WC) (cm)	76.1 (4.2)	82.1 (4.3)	88.0 (3.8)	94.9 (6.1)	<0.01
Blood pressure-related factors					
Systolic blood pressure (mmHg)	130.3 (19.0)	130.4 (18.0)	134.6 (16.4)	137.2 (19.0)	<0.01
Diastolic blood pressure (mmHg)	78.3 (11.1)	78.9 (12.8)	82.2 (11.5)	83.0 (11.9)	<0.01
Elevated blood pressure (Present) (%)	25 (29.8)	38 (31.7)	55 (44.0)	54 (47.8)	0.01
Lipid-related items					
High-density lipoprotein cholesterol (HDL-C) (mg/dL)	67.8 (15.7)	59.3 (14.3)	56.7 (14.9)	50.1 (10.6)	<0.01
Low-density lipoprotein cholesterol (LDL-C) (mg/dL)	111.9 (23.4)	128.4 (27.6)	125.9 (29.3)	131.2 (28.1)	<0.01
Triglycerides (TG) (mg/dL)	126.0 (111.8)	133.1 (84.9)	187.9 (158.2)	179.4 (107.9)	<0.01
Dyslipidemia (Present) (%)	26 (31.0)	61 (50.8)	82 (65.6)	72 (63.7)	<0.01
Glucose-related items					
Hemoglobin A1c (HbA1c) (%)	5.43 (0.93)	5.46 (0.48)	5.84 (0.87)	5.86 (1.09)	<0.01
Glucose tolerance impairment (Present) (%)	9 (10.7)	16 (13.3)	38 (30.4)	36 (31.9)	<0.01
Healthy lifestyle characteristics					
Alcohol consumption (non-drinker or moderate consumption)	68 (81.0)	103 (85.8)	99 (79.2)	102 (90.3)	0.10
Smoking behavior (non-current smoker)	56 (66.7)	83 (69.2)	82 (65.6)	66 (58.4)	0.36
Exercise frequency (two or more times per week)	34 (40.5)	40 (33.3)	32 (25.6)	27 (23.9)	0.04
Body mass index (18.5–24.9)	74 (88.1)	111 (92.5)	77 (61.6)	12 (10.6)	<0.01
Hours of sleep (6–9)	61 (72.6)	83 (69.2)	97 (77.6)	83 (73.5)	0.52
Breakfast (every morning)	78 (92.9)	113 (94.2)	112 (89.6)	96 (85.0)	0.09
Snacking between meals (none)	77 (91.7)	103 (85.8)	110 (88.0)	95 (84.1)	0.43
Total number of healthy lifestyle items	5.3 (1.3)	5.3 (1.2)	4.9 (1.3)	4.3 (1.1)	<0.01

[a] P values for trend were estimated using the Jonckheere–Terpstra test for continuous items and the Cochran–Armitage two-sided test for categorical items

Specific characteristics of visceral fat mass are shown in Table 2. Positive correlations were identified between visceral fat quartiles and BMI, WC, SBP, DBP, LDL-C, TG, and HbA1c levels. In contrast, visceral fat quartiles were inversely correlated with HDL-C levels. As for healthy lifestyle characteristics, visceral fat mass was negatively correlated with exercise frequency (two or more times per week), ideal BMI, breakfast (every morning), and total number of healthy lifestyle items.

Logistic regression analysis was used to determine odds ratios for lifestyle-related disorders according to visceral fat mass (Table 3). In Model 1 [adjusted for age (10 year increase) and BMI (18.5–24.9 kg/m^2)], visceral fat quartiles were significantly and positively associated with the prevalence of dyslipidemia, as compared to quartile Q1 [Q2: odds ratio (OR) = 2.34, 95 % confidence interval (CI) = 1.29–4.24; Q3: OR = 4.52, CI = 2.44–8.38; Q4: OR = 4.22, CI = 2.01–8.85]. The prevalence of impaired glucose tolerance was also significantly and positively associated with quartiles Q3 and Q4 (Q3: OR = 3.26, CI = 1.45–7.37; Q4: OR = 3.16, CI = 1.25–8.01). However, no association was observed between visceral fat quartiles and prevalence of elevated blood pressure. In Model 2 [adjusted for age (10 year increase) and total number of healthy lifestyle items], visceral fat quartiles were significantly and positively associated with the prevalence of dyslipidemia, as compared to quartile Q1 (Q2: OR = 2.33, CI = 1.29–4.22; Q3: OR = 4.32, CI = 2.36–7.90; Q4: OR = 3.77, CI = 2.00–7.09). The prevalence of elevated blood pressure and impaired glucose tolerance was also significantly and positively associated with quartiles Q3 and Q4 (Q3: OR = 1.85,

Table 3 Odds Ratios for lifestyle-related disorders according to visceral fat mass (Logistic regression analysis)

Visceral fat mass (kg)	Bivariate[a]			Multivariate					
				Model 1[d]			Model 2[e]		
	OR[b]	95 % CI[c]	*P*	OR[b]	95 % CI[c]	*P*	OR[b]	95 % CI[c]	*P*
Elevated blood pressure									
Q1 ≤ 1.2	Reference			Reference			Reference		
1.2 < Q2 ≤ 1.8	1.07	0.58–1.96	0.83	1.09	0.59–2.02	0.78	1.07	0.58–1.97	0.83
1.8 < Q3 ≤ 2.5	1.84	1.02–3.33	0.04	1.61	0.88–2.96	0.13	1.85	1.02–3.36	0.04
2.5 < Q4	2.23	1.22–4.08	<0.01	1.50	0.73–3.10	0.27	2.26	1.21–4.23	0.01
Dyslipidemia									
Q1 ≤ 1.2	Reference			Reference			Reference		
1.2 < Q2 ≤ 1.8	2.35	1.30–4.23	<0.01	2.34	1.29–4.24	<0.01	2.33	1.29–4.22	<0.01
1.8 < Q3 ≤ 2.5	4.46	2.45–8.12	<0.01	4.52	2.44–8.38	<0.01	4.32	2.36–7.90	<0.01
2.5 < Q4	4.06	2.21–7.46	<0.01	4.22	2.01–8.85	<0.01	3.77	2.00–7.09	<0.01
Glucose tolerance impairment									
Q1 ≤ 1.2	Reference			Reference			Reference		
1.2 < Q2 ≤ 1.8	1.22	0.51–2.94	0.65	1.24	0.51–2.97	0.63	1.21	0.50–2.91	0.67
1.8 < Q3 ≤ 2.5	3.55	1.60–7.87	<0.01	3.26	1.45–7.37	<0.01	3.32	1.49–7.42	<0.01
2.5 < Q4	4.00	1.78–8.97	<0.01	3.16	1.25–8.01	0.02	3.47	1.51–7.95	<0.01

[a] Bivariate regression analysis was adjusted for age (10 year increase); [b]Odds ratio; [c]95 % confidence interval; [d]Model 1 was adjusted for age (10 year increase) and body mass index (18.5–24.9); [e]Model 2 was adjusted for age (10 year increase) and total number of healthy lifestyle items based on Breslow's seven health practices

CI = 1.02–3.36; Q4: OR = 2.26, CI = 1.21–4.23 for elevated blood pressure) (Q3: OR = 3.32, CI = 1.49–7.42; Q4: OR = 3.47, CI = 1.51–7.95 for impaired glucose tolerance).

Significant positive correlations were observed for WC and BMI (WC: $r = 0.870$, $P < 0.01$; BMI: $r = 0.876$, $P < 0.01$).

Visceral fat mass (≥1.8 kg) was compared to WC, and appropriate cutoff values, sensitivity, specificity, and AUC were 85.3 cm, 0.849, 0.833, and 0.938, respectively. When compared to BMI, these variables were 23.25 kg/m^2, 0.916, 0.858, and 0.945, respectively (Figs. 1, 2). As for (ROC) curve analysis of lifestyle-related disorders for visceral fat mass (≥1.8 kg), sensitivity, specificity, and AUC were as follows: (1) elevated blood pressure: 0.660, 0.509, and 0.596, (2) dyslipidemia: 0.642, 0.662, and 0.570, and (3) impaired glucose tolerance: 0.650, 0.7625, and 0.503.

Discussion

This single hospital study revealed that visceral fat mass was significantly and positively associated with dyslipidemia, elevated blood pressure, and impaired glucose tolerance among Japanese men who were not receiving medications for lifestyle-related disorders and did not have medical histories of atherosclerotic disorders. In addition, a visceral fat mass of 1.8 kg might be identified as a cutoff value for predicting the onset of lifestyle-related disorders after adjusting for confounding factors. Visceral fat mass was closely and positively correlated with WC and BMI, with estimated cutoff points of 85.3 cm and 23.25 kg/m^2 for WC and BMI, respectively, correlating with a visceral fat mass of 1.8 kg. To our knowledge, this is the first report to use BIA methods to examine the association between visceral fat mass and the prevalence of lifestyle-related disorders.

There was a highly significant positive correlation between the amount of visceral fat and both WC and BMI. Moreover, visceral fat mass ≥1.8 kg was significantly associated with elevated blood pressure, dyslipidemia, and impaired glucose tolerance. An appropriate WC cutoff point correlating to 1.8 kg of visceral fat was determined to be 85.3 cm. It is possible that 1.8 kg of visceral fat may be comparable to 85 cm of WC among Japanese men. Several studies have examined associations between WC and visceral fat estimates by CT scan or MRI to diagnose central obesity, and have defined the WC cutoff point as corresponding to 100 cm^2 of visceral fat in each country or ethnic group [6, 19, 20]. Specifically, cutoff points for WC among Japanese individuals are 85 cm for men, and 90 cm for women, as recommended by The Japanese Society of Internal Medicine [19]. However, the International

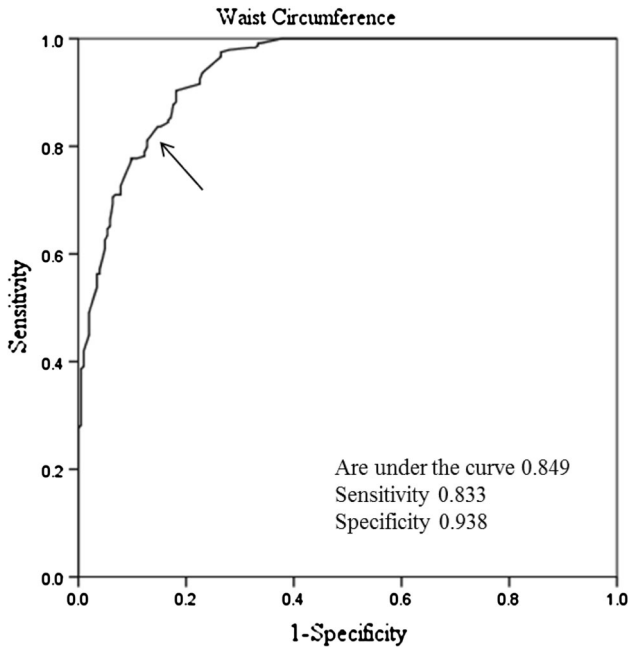

Fig. 1 Receiver operating characteristic curve analysis of waist circumference for visceral fat mass (≥1.8 kg)

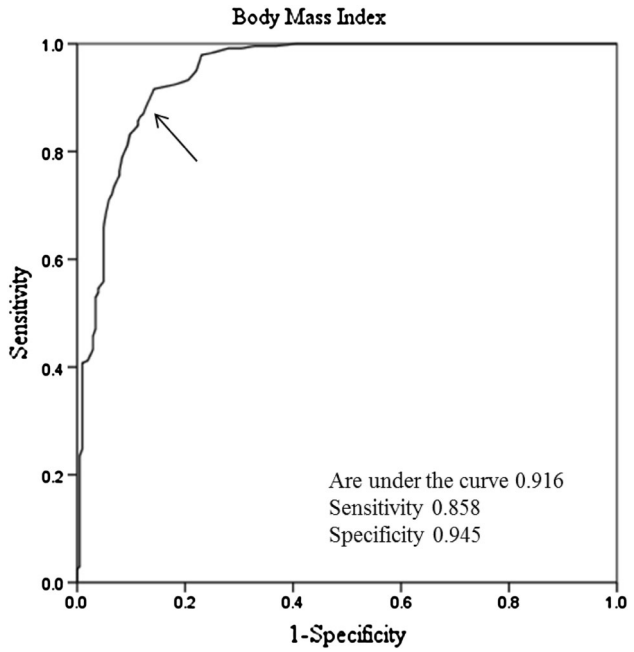

Fig. 2 Receiver operating characteristic curve analysis of waist body mass index for visceral fat mass (≥1.8 kg)

Diabetes Federation (IDF) suggests Asian-specific WC cutoff points of 90 cm for men and 85 cm for women [20]. Thus, these cutoff points are currently under debate. The results of this study suggest that a WC value of 85 cm could be the cutoff point for diagnosing central obesity among Japanese men. However, cutoff point of WC is still controversial and large-scale, multi-center studies are needed to further assess WC criteria using several methods.

BMI has been shown to be strongly, and positively correlated with visceral fat mass. BMI is a traditional and convenient anthropometric measurement, and has been widely used to assess obesity. In Japan, the cutoff value used for diagnosing obesity is 25 kg/m^2 [21]. However, previous studies have reported that Asians, including Japanese individuals, are prone to obesity-related morbidity and mortality at lower BMI levels than Caucasians [22]. In this study, the established appropriate cutoff value of 1.8 kg of visceral fat correlated with a BMI of 23.25 kg/m^2. This value closely approximates the World Health Organization's recommendation of a BMI cutoff value of 23 kg/m^2 for public health action as moderate to high risk [22]. Thus, lifestyle interventions that maintain lower BMI levels may be necessary to prevent lifestyle-related disorders.

This study has several limitations, including selection bias. The study was conducted in a single hospital in Fukushima Prefecture, Japan, and participants were limited to those who voluntarily underwent medical check-ups. These participants may have had increased awareness of health conditions and healthy lifestyle practices. In addition, women were not included in the analysis. Large-scale, multi-center studies that include female participants will be needed in the future. This study also did not utilize CT or MRI to assess trunk fat components, and therefore could not analyze the correlation between visceral fat estimated by CT or MRI and that estimated by BIA. In addition, the studies to examine the accuracy of estimating visceral fat mass using BIA among Japanese have been limited [9, 23]. Although previous studies have reported good correlation between measurements by CT or MRI and BIA, their correlation among Japanese participants has yet to be determined.

This cross-sectional study revealed that visceral fat mass ≥1.8 kg, as estimated by BIA, was significantly and positively associated with elevated blood pressure, dyslipidemia, and impaired glucose tolerance. Visceral fat mass was also strongly and positively correlated with WC and BMI, with appropriate cutoff values of 85.3 cm and 23.25 kg/m^2, respectively. BIA may be useful for assessing visceral fat mass, and these findings provide important evidence supporting the use of BIA for early and accurate detection and prevention of central obesity that may lead to lifestyle-related disorders.

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Conflict of interest The authors have no conflicts of interest to declare.

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